CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR

Cross-References to Related Applications, If Any:

This application claims priority of Japanese Application No.2003-089841 filed on March 28, 2003 and entitled "CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR".

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to a control valve for a variable displacement compressor for use in a refrigeration cycle of an automotive air conditioner, and more particularly to a control valve for a variable displacement compressor, for controlling a difference between discharge pressure and suction pressure in the variable displacement compressor such that the difference becomes equal to constant differential pressure set by an electromagnetic solenoid which is duty ratio controlled.

(2) Description of the Related Art

In a variable displacement compressor for use in a refrigeration cycle of an automotive air conditioner, a control valve therefor opens and closes a communication passage for communicating between a discharge chamber and a crankcase so as to control pressure in the crankcase into which high-pressure refrigerant is introduced from the discharge chamber, whereby the inclination angle of a

swash plate is controlled to control the displacement of refrigerant compressed by the piston. As methods of control of the displacement, there are known a method of controlling the displacement by sensing suction pressure and controlling the pressure in the crankcase in response to a change in the suction pressure, and a method (see e.g. Japanese Unexamined Patent Publication (Kokai) No. 2001-132650 (Paragraph Nos. [0026] to [0031], FIG. 1)) of controlling the displacement by sensing differential pressure between discharge pressure and suction pressure and controlling the pressure in the crankcase such that the differential pressure becomes equal to a predetermined value.

A control valve for use in controlling the displacement carries out the displacement control by supplying a current having a value corresponding to a set displacement, to an electromagnetic coil of an electromagnetic solenoid. In some cases, the displacement control is carried out by supplying a pulse current having a frequency of approximately 400 Hz, and changing the duty ratio of the pulse current. The control valve which is duty ratio controlled has a set load thereof set based on an average current value of current supplied to the electromagnetic solenoid, which is dependent on the duty ratio, and is capable of controlling the displacement of refrigerant from the variable displacement compressor (see e.g. Japanese Unexamined Patent Publication (Kokai) No.

2001-342946 (Paragraph No. [0019])).

In a control valve of a type that senses differential pressure between discharge pressure and suction pressure, there is employed a ball valve having a ball-shaped valve element, a needle valve or a tapered valve, having a tapered valve element, a flat valve having a planar valve element, or the like. The flow rate of refrigerant flowing from the discharge chamber to the crankcase is controlled by changing the lift of a valve element. When the variable displacement compressor is operated with the minimum displacement, the lift is controlled to be maximum, whereas when the variable displacement compressor is operated with the maximum displacement, the lift is controlled to be minimum, in other words, the control valve is placed in its valve-closed state.

However, in the control valve which is duty ratio controlled, the valve element and the shaft for actuating the valve element are performing micro vibration in the longitudinal direction of the control valve, so that when the valve element performs valve-closing operation, or when the valve element is caused to move in the valve-closing direction in response to an increase in the suction pressure occurring when it is close to the valve-closing position, the valve element is moved in the valve-opening direction after hitting against a valve seat associated therewith. This results in non-linear lift

characteristics of the control valve.

Further, during valve-closing operation, the valve element performing micro vibration is directly and repeatedly collides against the valve seat associated therewith. This causes degradation of durability of the valve element and the valve seat.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above described points, and an object thereof is to provide a control valve for a variable displacement compressor, which controls the differential pressure between discharge pressure and suction pressure such that the differential pressure becomes equal to differential pressure set by duty ratio control, and is improved in characteristics thereof when it is in the vicinity of the valve-closing position.

To solve the above problem, the present invention provides a control valve for a variable displacement compressor, for controlling a difference between discharge pressure and suction pressure in the variable displacement compressor such that the difference becomes equal to constant differential pressure set by an electromagnetic solenoid which is duty ratio controlled, characterized in that a valve section that carries out opening and closing control of a passage between a first port into which refrigerant is introduced and a second port from which the

refrigerant is guided out is formed by a spool valve.

The above and other objects, features and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view schematically showing a control valve according to a first embodiment of the present invention.

FIG. 2 is a cross-sectional view schematically showing a control valve according to a second embodiment of the present invention.

FIG. 3 is a cross-sectional view schematically showing a control valve according to a third embodiment of the present invention.

FIG. 4 is a cross-sectional view schematically showing a control valve according to a fourth embodiment of the present invention.

FIG. 5 is a cross-sectional view schematically showing a control valve according to a fifth embodiment of the present invention.

FIG. 6 is a cross-sectional view schematically showing a control valve according to a sixth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

FIG. 1 is a cross-sectional view schematically showing a control valve according to a first embodiment of the present invention.

The control valve comprises a valve section 10 and a solenoid section 20, and forms a control valve of an external variable control type. When the control valve is incorporated in a variable displacement compressor, not shown, it is disposed such that it is across a communication passage communicating between a discharge chamber and a crankcase, and at the same time communicates with a suction chamber.

The valve section 10 has a port 12 formed in a longitudinal end of a body 11, which communicates with the discharge chamber of the variable displacement compressor, for introducing refrigerant at discharge pressure Pd, a port 13 formed in a side of the body 11, which communicates with the crankcase of the variable displacement compressor, for guiding out refrigerant at controlled pressure Pc, and a port 14 formed in the side of the body 11 at a location toward the solenoid section 20, which communicates with the suction chamber of the variable displacement compressor, for receiving suction pressure Ps.

The valve section 10 has a spool valve provided in a

passage between the port 12 and the port 13. More specifically, a spool valve element 15 axially movably held by the body 11 is disposed in a manner opposed to a valve seat 16 such that the spool valve element 15 can be moved into and away from a valve hole of the valve seat 16 from a downstream side thereof, and urged by a spring 17 in the valve-opening direction. Further, the spool valve element 15 is in abutment with a shaft 18 axially movably held by the body 11, on the side toward the solenoid section 20. The shaft 18 is configured such that it receives the suction pressure Ps at an end face thereof opposite to an end thereof in abutment with the spool valve element 15.

The spool valve element 15 is configured such that an end thereof inserted into the valve hole has an outer diameter smaller than an inner diameter of the valve hole by a predetermined value. As a result, when the end of the spool valve element 15 is inserted into the valve hole, a predetermined clearance is provided between the end and an inner wall surface of the valve hole, and when the spool valve is open, the clearance functions as an orifice having a fixed cross-sectional area of a refrigerant passage.

The solenoid section 20 has a sleeve 22 having an electromagnetic coil 21 provided around a periphery thereof. A core 23 forming a fixed core is rigidly fixed to one end of the sleeve 22 on the side toward the valve

section 10. Further, a plunger 24 forming a movable core is axially movably disposed in the sleeve 22, in a state sandwiched by springs 25 and 26. The plunger 24 is rigidly fixed to a shaft 27 axially arranged therein. One end of the shaft 27 is in abutment with the shaft 18 that senses the suction pressure Ps, and the other end thereof is supported by a closing part 28 fitted in an open end of the sleeve 22. When the electromagnetic coil 21 is energized, a pulse current having a frequency of approximately 400 Hz is supplied to the electromagnetic coil 21, and an attractive force is generated between the core 23 and the plunger 24 in dependence on a change in the average current value caused by changing the duty ratio of the pulse current.

Now, when the pulse current having a predetermined duty ratio is supplied to the electromagnetic coil 21, and the plunger 24 is attracted by the core 23, the shaft 27 of the solenoid section 20 pushes the shaft 18 that senses the suction pressure Ps, and the spool valve element 15 is inserted into the valve hole against the urging force of the spring 17. As a result, refrigerant introduced into the port 12 is caused to flow through the orifice formed by the clearance between the spool valve element 15 and the valve hole and a controlled gap between the spool valve element 15 and the valve seat 16, and then from the port 13 to the crankcase. At this time, the control valve forms a valve for controlling the pressure Pc in the

crankcase such that differential pressure between the discharge pressure Pd and suction pressure Ps in the variable displacement compressor becomes equal to constant differential pressure set by the solenoid section 20 which is duty ratio controlled. More specifically, if the differential pressure between the discharge pressure Pd and the suction pressure Ps becomes larger than the set differential pressure, the spool valve is operated in the valve-opening direction to raise the pressure Pc in the crankcase and thereby reduce the displacement of the variable displacement compressor, whereby the differential pressure between the discharge pressure Pd and the suction pressure Ps is reduced. Inversely, if the differential pressure between the discharge pressure Pd and the suction pressure Ps becomes smaller than the set differential pressure, the spool valve is operated in the valve-closing direction to reduce the pressure Pc in the crankcase and thereby increase the displacement of the variable displacement compressor, whereby the differential pressure between the discharge pressure Pd and the suction pressure Ps is increased.

When a pulse current having a maximum duty ratio flows through the electromagnetic coil 21, a stepped portion of the spool valve element 15 is brought into abutment with the valve seat 16 to place the valve section 10 in its valve-closed state, whereby the variable displacement compressor is operated with the maximum

displacement. It should be noted that when the spool valve element 15 is going to be brought into abutment with the valve seat 16, the duty ratio is close to the maximum value, so that the axial stroke of micro vibration of the spool valve element 15 is very small, whereby it is possible to prevent the lift characteristics and durability of the control valve from being degraded by hitting of the spool valve element 15 against the valve seat 16. When the electromagnetic coil 21 is in a deenergized state, the plunger 24 is moved in a direction away from the core 23 by the urging force of the spring 17 to place the valve section 10 in its valve-open state, whereby the variable displacement compressor is operated with the minimum displacement.

FIG. 2 is a cross-sectional view schematically showing a control valve according to a second embodiment of the present invention. It should be noted that in FIG. 2, component elements identical to those shown in FIG. 1 are designated by the same reference numerals, and detailed description thereof is omitted.

This control valve is configured such that the spool valve element 15 and the shaft 18 receiving the suction pressure Ps, of the control valve according to the first embodiment, are integrally formed with each other, and the spring 17 urging the spool valve element 15 in the valve-opening direction is omitted but the spring 25 of the solenoid section 20 is caused to play the role of the

spring 17 as well.

Since the spool valve element 15 and the shaft 18 are integrally formed with each other, and the spring 17 is omitted, it is possible to reduce the number of component parts of the control valve, thereby making it possible to manufacture the control valve at low costs.

The operation of the control valve constructed as above is the same as that of the control valve according to the first embodiment, and since the valve section 10 is formed by the spool valve to eliminate hitting of the valve element against the valve seat, it is possible to stabilize the characteristics of the valve.

FIG. 3 is a cross-sectional view schematically showing a control valve according to a third embodiment of the present invention. It should be noted that in FIG. 3, component elements identical to those shown in FIG. 1 are designated by the same reference numerals, and detailed description thereof is omitted.

This control valve is configured such that the spool valve element 15, the shaft 18 receiving the suction pressure Ps, and the shaft 27 of the solenoid section 20, of the control valve according to the first embodiment, are integrally formed with each other, and the spring 17 urging the spool valve element 15 in the valve-opening direction is omitted but the spring 25 of the solenoid section 20 is caused to play the role of the spring 17 as well.

Since the spool valve element 15, the shaft 18, and the shaft 27 are integrally formed with each other, and the spring 17 is omitted, it is possible to reduce the number of component parts of the control valve, thereby making it possible to manufacture the control valve at low costs.

The operation of the control valve constructed as above is also the same as that of the control valve according to the first embodiment, and since the valve section 10 is formed by the spool valve to eliminate hitting of the valve element against the valve seat, it is possible to stabilize the characteristics of the valve.

FIG. 4 is a cross-sectional view schematically showing a control valve according to a fourth embodiment of the present invention. It should be noted that in FIG. 4, component elements identical to those shown in FIG. 1 are designated by the same reference numerals, and detailed description thereof is omitted.

This control valve is distinguished from the control valves according to the first to third embodiments in which their valve section 10 has one spool valve disposed in the passage between the discharge chamber and the crankcase of the variable displacement compressor, in that a valve section thereof has two spool valves respectively disposed in a passage between the discharge chamber and crankcase, and a passage between the crankcase and suction chamber.

The valve section 10 of the control valve has the port 12 formed in the longitudinal end of the body 11, which communicates with the discharge chamber of the variable displacement compressor, for introducing refrigerant at discharge pressure Pd, a port 13a formed in the side of the body 11, which communicates with the crankcase of the variable displacement compressor, for guiding out refrigerant at controlled pressure Pc1, a port 13b formed in the side of the body 11 at a location toward the solenoid section 20, which communicates with the crankcase of the variable displacement compressor, for introducing refrigerant at pressure Pc2 (= Pc1) of the crankcase. Further, the core 23 of the solenoid section 20 having the body 11 fitted thereon is formed with the port 14 communicating with the suction chamber of the variable displacement compressor, for guiding out the controlled suction pressure Ps.

The valve section 10 has a first spool valve provided in a passage between the port 12 and the port 13a. More specifically, the spool valve element 15 axially movably held by the body 11 is disposed in a manner opposed to the valve seat 16 such that the spool valve element 15 can be moved into and away from the valve hole of the valve seat 16 from the downstream side thereof, and urged by the spring 17 in the valve-opening direction. Further, the spool valve element 15 is in abutment with the shaft 18 axially movably held by the body 11, on the

side toward the solenoid section 20.

The shaft 18 has a second spool valve formed at an opposite end thereof to the end in abutment with the spool valve element 15, for controlling the flow rate of refrigerant flowing from the crankcase to the suction chamber of the variable displacement compressor. More specifically, between the port 13b formed in the body 11 in a manner communicating with the crankcase and the port 14 formed in the body 11 in a manner communicating with the suction chamber, a valve hole is formed in the center of the core 23, for communication between the port 13b and the port 14. An end of the shaft 18 toward the solenoid section 20 forms a spool valve element 19 which can be moved into and away from the valve hole, and an end face thereof receives the suction pressure Ps.

Each of the spool valve elements 15 and 19 is configured such that an end thereof inserted into the valve hole associated therewith has an outer diameter smaller than an inner diameter of the valve hole by a predetermined value. As a result, when the end is inserted into the valve hole, a predetermined clearance is formed between the end and an inner wall surface of the valve hole. This clearance functions as an orifice having a fixed cross-sectional area of a refrigerant passage.

Now, when a pulse current with a predetermined duty ratio is supplied to the electromagnetic coil 21, and the plunger 24 is attracted by the core 23, the shaft 27 of

the solenoid section 20 pushes the spool valve element 19 in the valve-opening direction, and the shaft 18 pushes the spool valve element 15 in the valve-closing direction. As a result, in the first spool valve, the refrigerant introduced into the port 12 flows through the orifice formed by the clearance between the spool valve element 15 and the valve hole associated therewith and a controlled gap between the spool valve element 15 and the valve seat 16, and then from the port 13a to the crankcase. Simultaneously, in the second spool valve, the spool valve element 19 is moved away from the valve hole associated therewith, and the refrigerant returned from the crankcase flows to the suction chamber through a controlled gap between the spool valve element 19 and the valve seat associated therewith and an orifice formed by a clearance between the spool valve element 19 and the valve hole associated therewith. At this time, the control valve forms a valve responsive to the differential pressure between the discharge pressure Pd and the suction pressure Ps, for controlling the pressures Pc1 and Pc2 in the crankcase such that the differential pressure becomes equal to the constant differential pressure set by the solenoid section 20 which is duty ratio controlled. More specifically, if the differential pressure between the discharge pressure Pd and the suction pressure Ps becomes larger than the set differential pressure, the first spool valve is operated in the valve-opening direction, the

second spool valve is operated in the valve-closing direction to raise the pressures Pc1 and Pc2 in the crankcase to reduce the displacement of the variable displacement compressor, whereby the differential pressure between the discharge pressure Pd and the suction pressure Ps is reduced. Inversely, if the differential pressure between the discharge pressure Pd and the suction pressure Ps becomes smaller than the set differential pressure, the first spool valve is operated in the valve-closing direction, the second spool valve is operated in the valve-opening direction to reduce the pressures Pc1 and Pc2 in the crankcase to increase the displacement of the variable displacement compressor, whereby the differential pressure between the discharge pressure Pd and the suction pressure Ps is increased.

When a pulse current with the maximum duty ratio flows through the electromagnetic coil 21, the stepped portion of the spool valve element 15 is brought into abutment with the valve seat 16, whereby the first spool valve is fully closed, and the spool valve element 19 is moved away from the valve hole associated therewith to thereby fully open the second spool valve. This causes the variable displacement compressor to be operated with the maximum displacement.

When the electromagnetic coil 21 is in a deenergized state, the first spool valve is fully opened and the second spool valve is fully closed, by the urging force of

the spring 17, whereby the variable displacement compressor is operated with the minimum displacement.

FIG. 5 is a cross-sectional view schematically showing a control valve according to a fifth embodiment of the present invention. It should be noted that in FIG. 5, component elements identical to those shown in FIG. 4 are designated by the same reference numerals, and detailed description thereof is omitted.

This control valve is configured such that the spool valve element 15, the spool valve element 19, and the shaft 18, of the control valve according to the fourth embodiment, are integrally formed with each other, and the spring 17 urging the spool valve element 15 in the valve-opening direction is omitted but the spring 25 of the solenoid section 20 is caused to play the role of the spring 17 as well.

Since the spool valve elements 15 and 19 and the shaft 18 are integrally formed with each other to thereby omit the spring 17, it is possible to reduce the number of component parts of the control valve, thereby making it possible to manufacture the control valve at low costs.

The operation of the control valve constructed as above is the same as that of the control valve according to the fourth embodiment, and since the valve section 10 is formed by the two spool valves to eliminate hitting of the valve element against the valve seat, it is possible to stabilize the characteristics of the valve.

FIG. 6 is a cross-sectional view schematically showing a control valve according to a sixth embodiment of the present invention. It should be noted that in FIG. 6, component elements identical to those shown in FIG. 5 are designated by the same reference numerals, and detailed description thereof is omitted.

This control valve is configured such that the spool valve element 15, the shaft 18, the spool valve element 19, and the shaft 27 of the solenoid section 20, of the control valve according to the fourth embodiment, are integrally formed with each other, and the spring 17 urging the spool valve element 15 in the valve-opening direction is omitted but the spring 25 of the solenoid section 20 is caused to play the role of the spring 17 as well. As a result, it is possible to reduce the number of component parts of the control valve, thereby making it possible to manufacture the control valve at low costs.

The operation of the control valve constructed as above is also the same as that of the control valve according to the fourth embodiment, and since the valve section 10 is formed by the two spool valves to eliminate hitting of the valve element against the valve seat, it is possible to stabilize the characteristics of the valve.

Although the preferred embodiments of the present invention have been described in detail hereinabove, the present invention is not particularly limited to these embodiments. For instance, although the control valves

according to the first to third embodiments control the flow rate of refrigerant supplied from the discharge chamber of the variable displacement compressor to the crankcase thereof, by way of example, this is not limitative, but the present invention can also be applied to a type of a valve which controls the flow rate of refrigerant drawn from the crankcase into the suction chamber.

Further, although in the control valves according to the fourth to sixth embodiments, both of the valve for controlling the flow rate of refrigerant supplied from the discharge chamber of the variable displacement compressor to the crankcase thereof, and the valve for controlling the flow rate of refrigerant drawn from the crankcase into the suction chamber are formed by spool valves, this is not limitative, but only one of the valves may be formed by a spool valve.

As described heretofore, in the present invention, the valve section of the control valve for a variable displacement compressor, for controlling the difference between discharge pressure and suction pressure in the variable displacement compressor such that the difference becomes equal to constant differential pressure set by an electromagnetic solenoid which is duty ratio controlled is formed by a spool valve. This prevents a valve element and a valve seat from colliding against each other when the valve is in the vicinity of the valve-closing position,

which makes it possible to enhance the lift characteristics of the valve and improve durability of component parts of same.

The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.